A silvicultural systems perspective on changing Canadian forestry practices

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ABSTRACT

Canadian forestry practices are changing to meet evolving forest management objectives, and these changes are frequently accompanied by new terminology. We examine the interaction among changing objectives, changing practices, and terminology in three forest types across Canada. Altered silvicultural practices and systems can generally be described using traditional terminology, and applying new terminology may create confusion. The most notable developments in silvicultural practice involve timber harvests with greater levels of tree retention, and new terminology is being applied mainly to designate changed harvest patterns. Timber harvesting is a crucial silvicultural practice, but does not by itself constitute a silvicultural system. It is necessary to more thoroughly define long-term stand-level management objectives, and to delineate complete silvicultural systems that address these objectives. This will require better knowledge of the long-term effects of forestry practices, particularly those resulting in structurally complex stands.

Key words: silvicultural systems, forestry practices, terminology, harvesting, Canada, structural retention

RÉSUMÉ

Les pratiques forestières canadiennes subissent des modifications de façon à répondre aux objectifs d'aménagement forestier en évolution et ces changements sont fréquemment accompagnés d'une nouvelle terminologie. Nous étudions les interactions entre les objectifs changeants, les pratiques modifiées et la terminologie dans le cas de trois types de forêt retrouvés au Canada. Les pratiques et les modes sylvicoles modifiés peuvent être généralement décrits au moyen de la terminologie traditionnelle et l'utilisation d'une nouvelle terminologie pourrait engendrer de la confusion. Les développements les plus importants au niveau de la pratique de la sylviculture touchent la récolte de bois comprenant des niveaux plus élevés de rétention d'arbres, et la nouvelle terminologie est utilisée principalement pour désigner les nouveaux modèles de coupe. La récolte de bois constitue un élément essentiel en terme de pratique sylvicole, mais ne constitue pas en soi un régime sylvicole. Il est nécessaire de définir plus en profondeur les objectifs à long terme d'aménagement au niveau du peuplement et de circonscrire des régimes sylvicoles complets qui répondent à ces objectifs. Cela nécessitera une meilleure connaissance des effets à long terme des pratiques forestières, particulièrement dans le cas de ceux retrouvés dans des peuplements structurellement complexes.

Mots clés : régimes sylvicoles, pratiques forestières, terminologie, récolte, Canada, rétention structurelle

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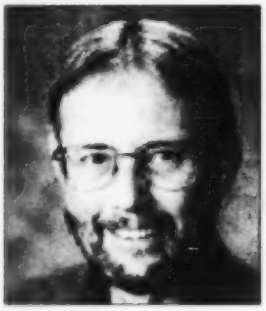

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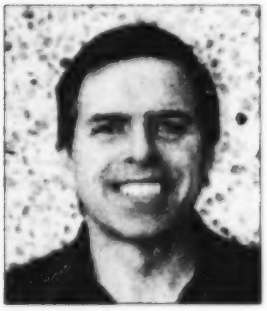

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Introduction

Canadian forests are being managed with increasing emphasis on values other than timber production. In particular, the conservation of forest biodiversity and the maintenance of ecological function have been accepted as important forest management objectives, leading to the adoption of management strategies such as the retention of ecological legacies (Franklin *et al.* 1997) and the emulation of natural disturbance regimes (Bergeron *et al.* 1999). The implementation of such strategies has resulted in a transformation of forestry practices (Groot 1995, Weetman 1995,

Lieffers *et al.* 1996). Evidence of change in practices is clear and unmistakable across the forest landscape: residual trees of various sizes and stand densities occupy many harvested areas; and treatment blocks are more variable and natural in size, shape, and arrangement. These changed practices have often generated new terminology.

Concurrent changes in forest management objectives, forestry practices, and terminology have the potential to create considerable confusion. The strong tendency to apply new terminology to changed forestry practices is especially problematic. New terminology provides an effective signal that something has changed, but it may also obscure the nature of the change. For example, novel terminology is sometimes applied to Canadian forestry practices that support changed management objectives, even when these practices are well known in other regions. This leads to questions about the characteristics of the "new" practice, and how it differs from that of essentially identical established practice elsewhere.

This problem is particularly acute in silviculture, because existing practices already include a broad range of treatments with a well-established terminology. Although truly original silvicultural treatments probably still can be devised, the realm of potential manipulations of stand structure has already been fairly thoroughly explored and described over the last two centuries.

The purpose of this article is to examine the interaction of changing forest management objectives, changing silvicultural practices, and the application of new terminology, using three examples from different forest types across Canada. We try to adopt a silvicultural systems perspective in this examination in accord with the long-term nature of forest management objectives.

Some Terminology

Forestry practices are actions taken at the stand or forest level to achieve forest management objectives. Forestry practices include not only silvicultural practices, but also forest management planning elements such as the diversification of silvicultural systems, the scheduling of stands to be harvested through time, and the arrangement of harvesting across the landscape.

Silvicultural treatments or **practices** are actions taken at the stand level to achieve forest management objectives. Ideally, a silvicultural treatment is designed and prescribed for a specific stand type and stage, with clear objectives, both short- and long-term. Although silvicultural treatments are applied at the stand scale, the division between stand and forest scales is not always well defined. For example, Smith *et al.* (1997) note that an uneven-aged stand could also be considered a collection of much smaller even-aged stands. Silvicultural treatments are the elements of silvicultural systems.

A **silvicultural system** is "a planned program of silvicultural treatment extending through the life of a stand" (Smith *et al.* 1997). This definition implies a fairly comprehensive control of stand structure and composition, but we note that comparatively rudimentary silvicultural programs are current across much of Canada. Constraints such as extensive areas of overmature timber, unbalanced age class structure, and low timber revenues (Weetman 1995) often limit silvicultural treatments to forest harvesting and regeneration. Such programs can still be considered to constitute silvicultural systems, as long as (i) reproduction is assured and (ii) there is reasonable expectation that the objectives for long-term stand development will be met.

Silvicultural systems have their roots in European forestry, and were developed during a period when timber production was the dominant goal, often in forests with relatively simple stand structure and composition (Weetman 1996). The focus of traditional silvicultural systems on timber production has led some to conclude that they are exclusively associated with this objective. Quite the opposite is true, however, since silviculturists have long recognized that silviculture can be directed at a variety of purposes:

> *"Silviculture is normally directed at the creation and maintenance of the kind of forest that will best fulfil the objectives of the owner. Returns from silviculture are generally thought of in terms of timber production, although it is not uncommon for owners to have other goals. The growing of wood may, in fact, have low priority among these objectives or none at all."* (Smith 1962).

Smith *et al.* (1997) have pointed out that understanding silviculture for timber production, which involves considerable control of stand composition and structure, makes the formulation of silviculture for other purposes comparatively straightforward. The difficulty in managing for other purposes is not so much in formulating the silviculture as in specifying affordable objectives of management.

Practices for Eastern Boreal Black Spruce Forests

In the eastern Canadian boreal forest, overmature natural stands of black spruce (*Picea mariana* (Mill.) BSP) frequently contain abundant advance regeneration of that species. Such two-storied stands are common on a range of sites in Québec, but further west are increasingly restricted to peatland sites. In yet older black spruce stands, break-up of the overstory and development of the understory advance regeneration results in stands with irregular size structures.

Advances in logging equipment and techniques have made it feasible to protect advance regeneration during harvest, and practices that aim to protect advance regeneration are termed "Careful Logging Around Advance Growth" (CLAAG) in Ontario, and "Coupe avec Protection de la Régénération et des Sols" (CPRS) in Québec.

Although the height of advance regeneration is variable, most stems are less than 2 m tall, and CLAAG/CPRS results in even-sized or regular stands. This is analogous to the shelterwood silvicultural system in managed stands, and it has been suggested that the use of advance regeneration in natural stands be termed a "**one-cut shelterwood system**" (Smith *et al.* 1997) or a "**natural shelterwood system**" (Weetman 1996). Such terminology would be much less confusing than the acronyms CLAAG and CPRS.

The natural shelterwood system is widely applied in eastern Canada because of the prevalence of overmature stands that have had an opportunity to accumulate advance regeneration. The system has been rapidly adopted primarily because it offers low-cost, reliable regeneration. Stand structure and development will likely parallel that of natural

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even-aged stands (Lussier *et al.* 2002). Because the regeneration can be 1 to 2 m tall at the time of harvest, there may be a reduction in the rotation length compared with regeneration by seeding or planting (Pothier *et al.* 1995, Lussier *et al.* 2002). There is some concern that on upland sites, this system may cause a shift in tree species composition from black spruce to balsam fir (*Abies balsamea* (L.) Mill.), trembling aspen (*Populus tremuloides* Michx.) and white birch (*Betula papyrifera* Marsh.).

The first application of the natural shelterwood system in a stand is also likely to be the last. In general, the regenerated stand will be managed by another silvicultural system, because it is unlikely that sufficient regeneration will establish spontaneously within the length of a usual forest rotation to allow a repetition of this system. It may be possible to implement a traditional shelterwood system using a series of intermediate harvests and experiments. Such systems are being carried out in pure black spruce and mixed black spruce/jack pine (*Pinus banksiana* Lamb.) forests.

Little vertical structure is retained with the natural shelterwood system when most stems are less than 2 m tall, but greater structural retention is possible in stands with a more irregular vertical structure. Operations that retain taller, but not yet merchantable, stems are termed "Coupe avec Protection de la Régénération Hautes et des Sols (CPHRS)" in Québec. Those that retain merchantable stems (> 10–12 cm dbh) are termed "Coupe avec Protection des Petites Tiges Marchandes (CPPTM)" in Québec, and, inexplicably, "Harvest with Regeneration Protection (HARP)" in Ontario.

The greater structural retention of CPHRS and CPPTM/HARP goes further in satisfying ecological objectives, but smaller stems usually far outnumber larger stems. The regenerated stand is still effectively even-sized, albeit with a range of stem heights, and subsequent management must be even-aged to address this dominant stand component.

In some cases, CPPTM/HARP results in a substantial number of larger residual stems, but this circumstance has not yet been integrated into a well-defined silvicultural system since there is still uncertainty on the long-term development of residual stands (Bédard *et al.* 2002). Depending on the post-harvest structure, such a treatment could be considered a **thinning of dominants** (Smith *et al.* 1997), implying subsequent even-aged management of the residual stand, or the first of a regular series of partial harvests constituting **uneven-aged management** (e.g., MacDonell and Groot 1996, Groot 2002). Stand development after practices that leave larger residuals may be similar to the development of stands that were logged using horses in the first half of the 20th century. The age and size structure of these stands is almost invariably irregular (Groot and Horton 1994).

The terms CPHRS and CPPTM have the virtue of providing some clarity about the sizes of trees to be protected, but convey little information about the overall silvicultural system. The term HARP is misleading because the treatment is aimed at protecting small merchantable stems rather than regeneration. The Ontario Silvicultural Guide compounds confusion about the role of the HARP treatment: HARP is described as maintaining uneven-aged stands, yet it is classified as a clearcut silvicultural system (OMNR 1997).

As forestry practices in black spruce evolve toward greater retention of larger residual stems, the need for knowledge about subsequent stand development becomes more acute. For example, information about appropriate cutting cycles and intensity in uneven-aged management is virtually non-existent.

There is a need to clarify the management objectives underlying the shift toward silvicultural systems implying greater tree retention. The development of CLAAG/CPRS was initially motivated by the need to reduce regeneration costs while curbing the negative impacts on soils of clearcutting, with little change in the main management objective (i.e., maximizing wood production with minimal investments). Although many forest ecologists agree on the need to increase tree and forest retention for closer-to-nature ecosystem management (Bergeron *et al.* 1999), retention criteria have yet to be developed that will lead to feasible and optimal compromises between wood production and protection of essential ecological attributes.

Practices for Boreal Mixedwood Forests

Mesic upland sites in the Canadian boreal forest support a coniferous and deciduous mosaic of pure stands and mixtures. The characteristic species on these sites across the boreal forest are trembling aspen and white spruce (*Picea glauca* (Moench) Voss); balsam poplar (*Populus balsamifera* L.), white birch, balsam fir, black spruce and jack pine also are components in proportions that vary both regionally and locally. Stand development often leads to an overstory dominated by trembling aspen and a well-stocked coniferous understory (white spruce in the western boreal forest and balsam fir in the east).

Management of aspen-spruce mixedwoods continues to be dominated by clearcut systems, or clearcuts with variable retention of trees left as patches or individuals. This "coarse filter approach" assumes that the retention of structure will allow maintenance of the ecological processes associated with similar structures in natural forests.

Lieffers *et al.* (1996), using mainly classical terminology, summarized a range of silvicultural systems that can be applied to western boreal mixedwood stands, with treatments taking advantage of initial stand conditions to achieve long-term desired outcomes. **Clearcutting, coppice, and shelterwood** silvicultural systems are feasible and result in even-aged stands, but opportunities for **single-tree selection** were also identified.

Among these systems, the **natural shelterwood system** (usually termed an understory protection system in the western boreal forest), carried out in vertically stratified trembling aspen/white spruce stands, has received the greatest attention in research, development, and application. Brace and Bella (1988) proposed a "stand tending and harvest scenario" for stands with this structure, which was implemented experimentally in Alberta as a "two stage harvesting and tending model" by Navratil *et al.* (1994). In this model, the aspen overstory and mature conifers are harvested, while protecting the white spruce understory.

In addition to releasing the spruce advance regeneration, the overstory harvest stimulates trembling aspen suckers, resulting in a new mixed hardwood/conifer stand. Brace and Bella (1988) used an individual tree growth model to project development of such stands, and concluded that this system would achieve substantial yields of white spruce. These

projections used simplifying assumptions, however, and the timing of treatments and the implications for growth and yield and long-term stand composition and structure require further elaboration (MacIsaac and Sauder 2001).

If white spruce advance regeneration is lacking, underplanting 10 or more years prior to the planned harvest of the aspen canopy is a feasible practice within the **shelterwood system** to establish a coniferous component in the regenerating stand (DeLong 2000). One approach is to target low-density aspen stands and plant without canopy thinning or understory site preparation. This strategy requires careful site selection, to avoid stands where heavy brush competition and herbivory may cause high mortality. A second approach, for denser canopies, is to underplant after uniformly thinning to about 500–700 stems/ha. This can be done in conjunction with a light understory shear blading or soil mixing treatment. Thinning and site preparation may damage the aspen roots, however, causing canopy dieback over time. Under appropriate circumstances, underplanting can favour establishment of white spruce without the requirements for aggressive vegetation control that can be encountered in a clearcut. It is also possible to create good conditions for planted white spruce in small openings (e.g., Groot *et al.* 1997). A coherent silvicultural system to manage the resultant species mosaic through time has yet to be developed, however.

In many mixedwood stands, the understory conifers are in the sapling and pole size classes; in these circumstances, treatments that remove overstory aspen to release coniferous crop trees are better considered as **thinnings of dominants** (Smith *et al.* 1997). Windthrow is a serious threat to mid- to large-sized understory white spruce after overstory removal, and a number of treatment variations have been devised to minimize wind damage (Navratil *et al.* 1994, MacIsaac *et al.* 1999).

Practices for Pacific Coastal Forests

Pacific coastal forests are dominated by conifers, primarily Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco var. *menziesii*), western hemlock (*Tsuga heterophylla* (Raf.) Sarg.) and redcedar (*Thuja plicata* Donn) at low elevations, and true firs (*Abies* spp.), mountain hemlock (*Tsuga mertensiana* (Bong.) Carr.) and yellow cypress (*Chamaecyparis nootkatensis* (D. Don) Spach) at elevations over 800 m. The mountainous character of coastal B.C. and Vancouver Island causes considerable longitudinal differentiation and forest cover varies from wet westerly aspects dominated by hemlock to dry easterly aspects dominated by Douglas-fir.

Many approaches have been taken to diversify silvicultural systems in Pacific coastal forests, including both even-aged and uneven-aged stand management and a variety of retention silviculture systems such as group- and single-tree-selection, shelterwood, and seed-tree systems (Daigle 1995, Arnott and Beese 1997). However, in coastal British Columbia, issues surrounding the harvesting of virgin forests have resulted in a move toward silvicultural systems that retain forest structure (large living and dead trees, coarse woody debris and heterogeneity of tree size) in perpetuity (Mitchell and Beese 2002).

In the U.S. Pacific Northwest, Franklin *et al.* (1997) advocated varying the level of retention in forest harvesting in order to maintain structural complexity. They correlated retention levels of less than 10% with traditional even-aged management using **clearcut**, **seed tree** and **shelterwood** systems, and retention levels of more than 70% with traditional **uneven-aged management selection** systems. Intermediate levels were felt to have no analogue in traditional silviculture, although it could well be argued that intermediate levels of removal could be effectively described as **thinnings**, a term that encompasses a wide array of partial harvests.

At the stand-level, dispersed and aggregated retention are two recognised spatial models for variable retention. Each has its advantages depending on operational and ecological objectives. However, additional benefits can be derived from the combination of the two approaches. In a sense, retained aggregates (larger than 0.25 ha) represent islands of structurally diverse, climatologically moderated habitat, while dispersed retention (individual trees) provides stepping-stones between those islands. In some jurisdictions, aggregate patches may be the only way to safely conserve structural elements that could only be reproduced over very long time frames, such as snags. As it has been implemented on the B.C. coast, retention levels are on the order of 10% to 20% with a mixture of aggregates and dispersed trees.

Mitchell and Beese (2002), recognizing that the variable retention harvesting strategies proposed by Franklin *et al.* (1997) did not constitute a coherent silvicultural system, sought to define a "variable retention" silvicultural system that aims to retain forest structure representative of the pre-harvest stand for very long time frames (hundreds of years), with considerations of biodiversity or aesthetics possibly taking precedence over timber production.

In order that a silviculture system be called variable retention more than 50% of the cutblock area must be under forest influence, defined as the biophysical effects of retained aggregates or single trees on the surrounding land (Mitchell and Beese 2002). However, the influence of retained trees being in the order of one or two tree lengths has been based primarily on climatic data from studies of transects across stand edges, and few studies have addressed the extent of forest influence from residual trees on biotic communities or ecological processes (e.g., nutrient cycling).

The long-term implications of retention systems are poorly understood. Since one of the prime objectives of those systems is the conservation of old-growth attributes, uncertainty surrounds the longevity of those attributes because of possibility of windthrow, fire and insect and disease attacks in the retained elements. Similarly, the persistence of forest influence is in question. At the landscape level, retention systems should reduce the fragmentation of forests that results from cutting small patches over a large area to meet timber supply goals because of the relaxation of limits on opening size that are imposed on clearcut systems.

The case of the retention system is a particularly interesting example of the complex relationship between changing forestry practices and terminology. Mitchell and Beese (2002) note that stand-level retention is attainable through classical silvicultural systems, but argue that the use of new terminology clarifies changes in the intent of management. They further argue that the need to manage retention at the

landscape scale as well as the stand scale calls for the definition of a new system.

Despite these arguments, there appears to be a substantial risk of increasing confusion by defining variable retention harvesting practices as a silvicultural system on this basis, since (i) treatments beyond the initial harvest entry have not been developed; (ii) the regeneration method is not clearly defined; (iii) the long-term effects of even the initial treatments are not well-understood, or even considered; and (iv) the landscape elements of the retention system might fit more comfortably within the realm of forest management planning than within a silvicultural system.

Discussion

There is little doubt that forestry practices in Canada are changing in response to changing objectives for forest management, brought about by ecological, social and economic pressures. Much of the change is in the direction of greater retention of trees during timber harvests.

New terminology is almost invariably attached to these changed forestry practices, but in most cases the practices could also be described using traditional silvicultural terminology. A virtue of traditional terminology is the clear distinction between silvicultural treatments and silvicultural systems; a failing of new terminology is that this distinction is often lost. Although part of the motivation for adopting new terminology is to emphasize that the objectives of forest management have changed, we believe that the interests of effective communication are not served by inventing new terminology for existing silvicultural practices in order to signal a change in management objectives.

Most of our examples of changed forestry practices from across Canada are harvests with greater levels of retention, and the new terminology typically describes only the harvest pattern. The focus on stand structure and composition immediately after harvest is an indication that forest management objectives may be inadequately defined. Ideally, management planning would result in long-term stand-level objectives to satisfy forest-level goals for wood supply, habitat supply, biodiversity conservation, and the maintenance of ecological function and aesthetic values. As noted previously, the specification of feasible long-term stand-level objectives that are consistent with forest-level goals may well be one of the most difficult tasks in forest management. The process of specifying these objectives will at the same time require that the silvicultural system be delineated, at least in rough terms.

Solving the joint problem of specifying long-term stand management objectives and outlining silvicultural systems requires knowledge about the long-term effects of forest practices on stand growth, structure, and composition. The amount of this knowledge generally decreases as the degree of retention increases, because much of the knowledge about the development of forest stands in Canada comes from observations of monospecific, even-aged stands that originated from large and intense natural disturbances such as fire or insect attack or from even-aged silvicultural systems. There is much less experience with mixed-species and structurally heterogeneous stands.

The impact of a lack of long-term silvicultural experience is exacerbated by the low number of treatment interventions characteristic of many Canadian silvicultural systems. When a silvicultural system comprises a regular series of treatments, there is greater opportunity for controlling stand development to satisfy management objectives. In contrast, if only one or two treatments make up the system, meeting objectives depends mainly on good forecasts of response to treatment.

There is a clear need to increase knowledge about the long-term effects of changing silvicultural practices (Weetman 1995). This knowledge can be obtained from a variety of sources, including: (i) long-term forestry practices experiments (e.g., Mitchell and Vyse 1999), (ii) chronosequence studies in natural irregular stands (e.g., Hedberg and Blackwell 1998), (iii) examination of historical analogues to current practices (e.g., Groot and Horton 1994), and (iv) empirical (e.g., Huang and Titus 1995) and more process-based stand dynamics models (e.g., Coates *et al.* 2003).

Dedication

This article is dedicated to the memory of George Marek, who, facing the challenge of devising silvicultural treatments for unmanaged boreal forests, responded with innovation, determination, and perseverance.

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